

Results of White-Tailed Deer (*Odocoileus virginianus*) Surveys in Watchung Borough in 2019

May 17, 2019

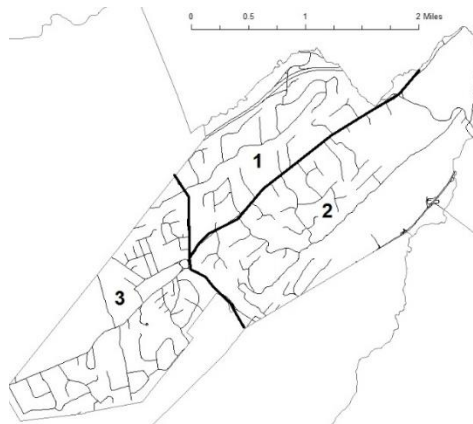
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Objective: We documented densities of white-tailed deer (*Odocoileus virginianus*) in Watchung Borough in early spring of 2019 using a combination of roadside spotlight survey and infrared drone techniques.

For spotlight surveys, the Borough was divided into three sections (Figure 1), which were surveyed simultaneously by two different teams of Raritan Valley Community College wildlife research interns, on 4/2/2018 (Section 1, 2, and 3), 4/20/2018 (Section 1,2, and 3). Surveys were conducted on clear nights from 9:30 PM to 2:00 AM, counting the number of deer for each 0.2 mile segment of road using high-powered flashlights (600 yard max. range), and measuring search area using laser rangefinders. Deer and search area data were entered in real-time in ArcCollector. Density was calculated by dividing the total number of deer observed by the total search area, and was determined for both the first and second round of surveys for the Borough as a whole, as well as for each individual segment. The average density was then calculated for each in order to estimate town-wide densities. The total deer population in the town was calculated by extrapolating the average number of deer observed per survey across the area of the town.

Because survey results may be biased by landscape and other factors, densities were also obtained from infrared drone surveys for quality control. Drone surveys were performed with a Zenmuse XT thermal imaging camera mounted on a DJI Inspire drone on three separate nights, with a minimum of one survey located within each road survey section. Surveys were conducted at night to allow for adequate thermal contrast between the landscape and deer, and only when conditions were suitable, with low/no winds or precipitation. All flights were conducted with an FAA-certified pilot aided by a visual observer. Each mission was flown below 400 feet above ground level in class G airspace, and under a night waiver as required by FAA regulations. All observations of deer and search areas were mapped in real time using ArcCollector. Densities from the drone surveys were calculated by total deer found divided by the search area covered by the drone.

Figure 1. Road-based spotlight survey sections in Watchung Borough



Spotlight Survey Results:

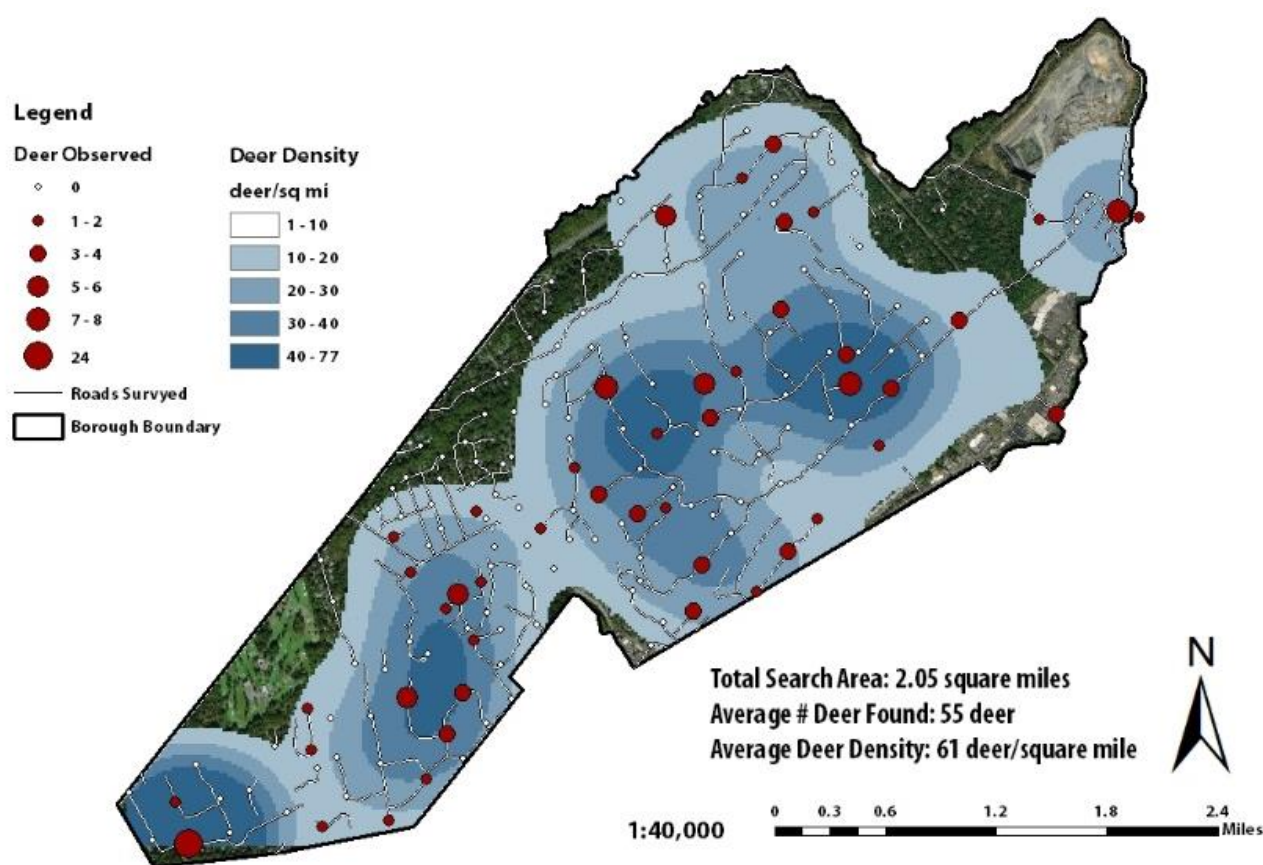
A total search area of 2.05 mi² was covered during each spotlight road-based survey, or 33.9% of the approximately 6.05 mi² in the Borough as a whole. A total of 155 deer were observed during the first census, resulting in a total density of 75.5 deer/mi². A total of 97 deer were observed during the second round of surveys, resulting in a density of 47.2 deer/mi².

The average density of deer for the Borough as a whole was 61.4 deer/mi². Groups of deer numbered from 1 to 24 individuals (average = 3). Numbers of deer and associated densities varied greatly between individual Borough sections and between surveys, from 27-66 deer per section, and densities of 45.5 to 96.9 deer/mi². Variation in maximum observed numbers and densities are displayed in Figure 2.

Table 1. Results of individual surveys for each section of Watchung Borough including search area (mi²), number of deer observed, and density (deer/mi²).

	Search Area	1st Survey		2nd Survey		Average Density
		# Deer	Density	# Deer	Density	
Section 1	0.58	28	48	27	47	61
Section 2	0.68	66	97	31	46	
Section 3	0.78	61	78	39	50	
TOTAL	2.05	155	76	97	47	

Figure 2. Number and density of deer observed during road-based spotlight surveys. Note that the deer density displayed in shades of blue does not show actual deer density per section, but merely density of *observed* deer from the road in order to illustrate spatial variation in deer distribution. The data illustrated is the greater results of the two surveys for each respective section of town.



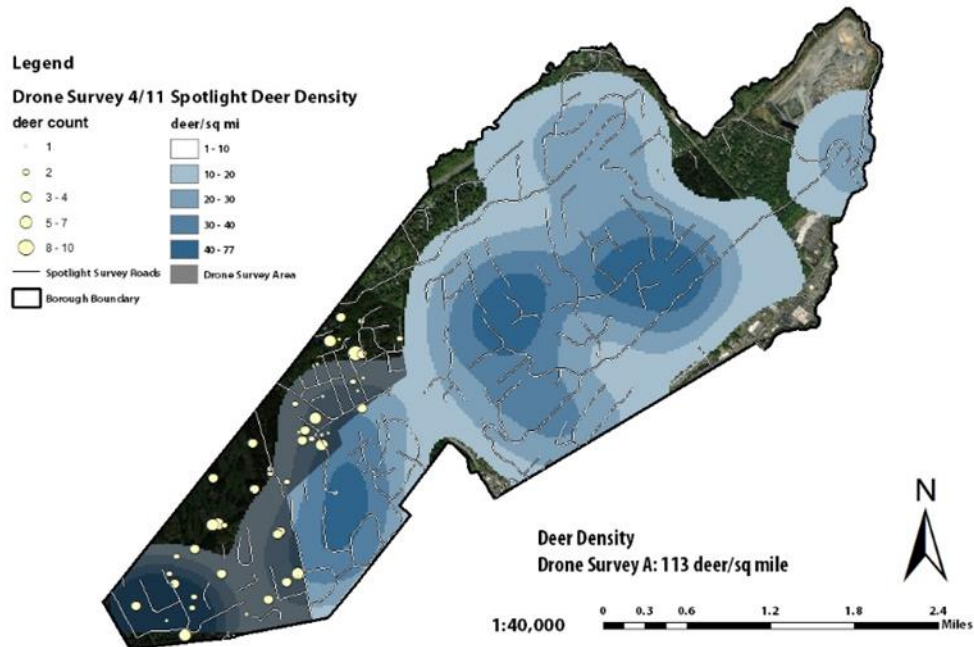
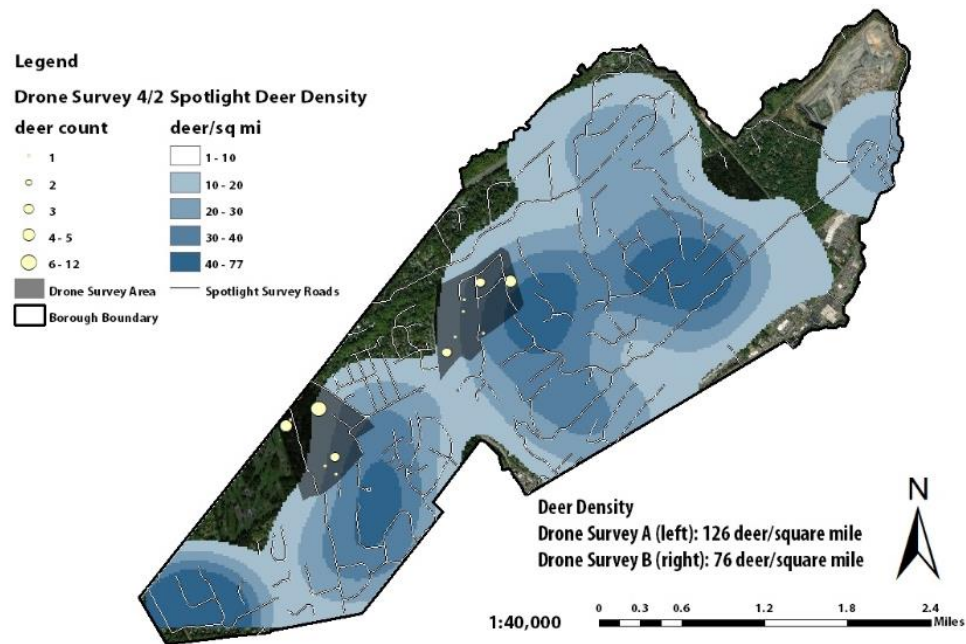
Drone Survey Results:

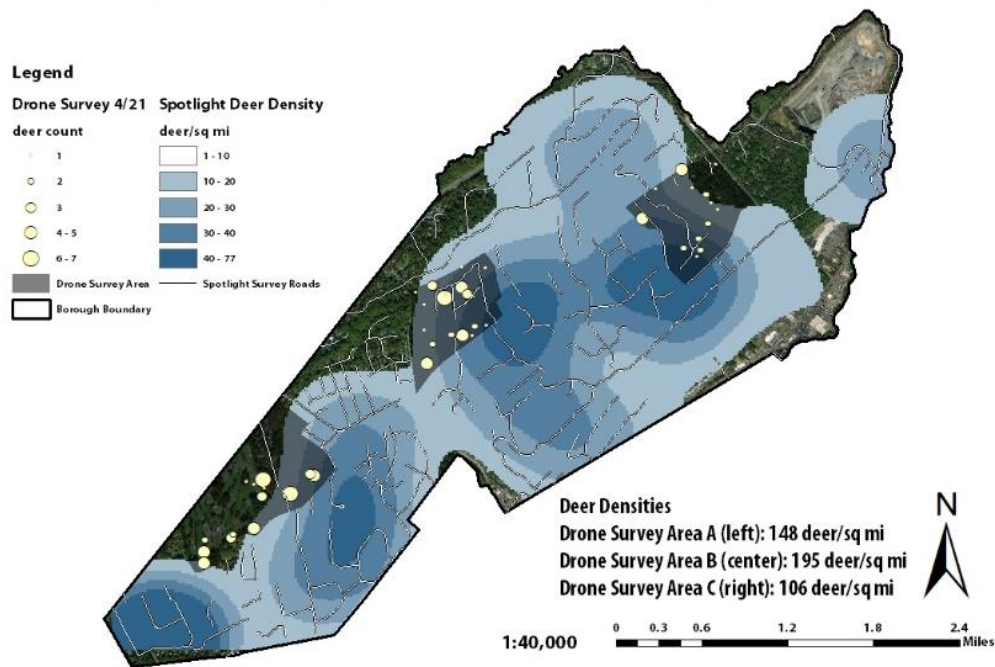
Drone surveys were done on three separate nights. Total search area of non-overlapping surveys resulted in 1.86 mi², or 30.7% of the Borough as a whole. Densities from the each drone surveys ranged between 103 deer/mi² and 148 deer/mi² with an average of 121 deer/mi² (Table 2, Figure 3). The greatest continuous survey area extent covered by the drone surveys in a single night was 1.42 mi² and resulted in a total of 160 deer for 113 deer/mi². Surveys from smaller, individual search areas found densities ranging from 76-195 deer/mi².

Table 2. Results of individual drone surveys for Watchung Borough including search area (mi²), number of deer observed, and density (deer/mi²).

	4/2/2019			4/11/2019			4/21/2019			Average Density
	Search Area	# Deer	Density	Search Area	# Deer	Density	Search Area	# Deer	Density	
Drone Survey A	0.2305	29	126	1.4187	160	113	0.4590	68	148	121
Drone Survey B	0.1976	15	76				0.2052	40	195	
Drone Survey C							0.2370	25	106	
TOTAL	0.4281	44	103	1.4187	160	113	0.9012	133	148	

Figure 3. Number and density of deer observed during drone surveys. Note that the deer density displayed in shades of blue are based on the spotlight deer surveys for comparison.





Average densities of deer of 61-121 deer/mi² obtained by spotlight and drone surveys in Watchung Borough in 2019 show an increasing trend from both the 40 deer/mi² observed in the spring of 2018 using the same methodologies (Kelly 2018a), and the 21-22 deer/mi² observed in the spring of 2017 using aerial and spotlight surveys, respectively (Kelly unpublished data; Vision Air Research 2017). Several possibilities may explain this increase, include a series of mild winters, immigration of deer from surrounding municipalities, limited deer harvest by hunting, increases in fecundity, or observer error. With females in this area regularly birthing 2-3 fawns per year, it is possible for populations to double in years with low mortality.

The high variation observed within and between individual spotlight and infrared surveys suggest significant spatial and/or temporal variation in deer densities at small scales within Watchung Borough. While deer movement between survey sections may be a factor, potentially leading to double or under-counting, all three sections were surveyed simultaneously in our studies, and deer ranges in suburban landscapes are highly local in the winter season after hunting has ended (Williams et al. 2008), suggesting this is not likely a factor. The discrepancies between the road-based and infrared surveys more likely the result of the physical limitations of the spotlight surveys in general (i.e., observing only deer that are visible from the road) and their consequent susceptibility to spatiotemporal variation in population patterns. Weather conditions that cause deer to seek greater cover, for example, or greater food availability away from roads, may dramatically reduce the likelihood of detection by spotlight surveys. While detectability is not a significant factor in this regard for infrared drones, the high variation in local densities observed in Watchung suggests that sample areas greater than the scale of local variation are needed with these methods to accurately estimate densities at large (e.g., town-wide) scales. The largest sample of 1.4 mi² collected in this study therefore likely provides the best estimate of current town-wide densities (113 deer/mi²), compared to the other, much smaller samples collected. Given the increased accuracy and decreasing costs of drone-based aerial infrared surveys, these methods are likely to present more reliable methods for surveying deer populations than road-based surveys in Watchung Borough in the future.

Despite the variation observed between survey methods, the results from Watchung Borough in 2019 remain consistently higher than both historical, statewide, and optimal deer densities for sustaining ecosystem health. Actual populations occurring throughout the remainder of the year are likely to be substantially higher. The most recent regional estimates of deer densities available from the New Jersey Department of Environmental Protection indicated minimum average densities to be as high as 78 deer/mi² (NJ Division of Fish and Wildlife 1999). However, these estimates are based off of harvest statistics from hunting, which may not be accurate in areas where hunting access is limited, such as the suburban or urban environments that characterize much of central and northeastern NJ (NJ Division of Fish and Wildlife 1999). Local surveys using direct counting methods (spotlight or infrared) have found local deer

densities to be in excess of 150-200 deer/mi² in some areas of New Jersey (NJDFW 1999, McWilliams et al. 2013). It is also important to note that the number and densities of deer observed in this study were recorded at the most conservative time of year; i.e., after the period of peak mortality from hunting and cold temperatures in the fall and winter months and before the birth of fawns in late spring. Given the high reproductive rates of deer, it is likely that the actual deer population size for the majority of the year is much higher than the survey results indicate.

Historical studies suggest that precolonial deer densities were likely to be approximately 5-11 deer/mi² (McCabe and McCabe 1997). Biological impacts to preferred browse species have been observed at densities above 10 deer/mi² (Horsley et al., 2003; deCalesta and Stout, 1997; Alverson et al., 1988; Frelich and Lorimer, 1985; Behrend et al., 1970) and impacts to forest regeneration, bird communities, invertebrates, and a host of other ecosystem variables above 15-20/mi² (McWilliams et al. 2018, Russell et al. 2017, Nuttle et al. 2011, Horsley et al. 2003, Drake et al. 2002, de Calesta 1994). The effects of overabundant deer are not limited to natural areas, but to human populations as well, costing millions of dollars a year from deer-vehicle collisions, damage to agricultural crops and landscaping, and impacts of Lyme's disease and other tick-borne diseases (Patton et al. 2018, Conover 2011). Accordingly, deer management practices that have successfully reduced deer populations have been found to result in significant decreases in deer-vehicle collisions in New Jersey and other areas (Williams et al. 2013). It is therefore advisable that targets for deer management should be set at 10 deer/mi² to maintain the greatest benefits for social, economic, and ecosystem integrity as possible (Kelly 2019). Given the high densities and increasing population trends of deer populations in Watchung, along with the limited response of forest regeneration on hunted properties compared to other areas where more aggressive deer management is taking place (Kelly 2018b), modifications to the Borough's deer management practices should be considered in order to achieve greater benefits of these kinds for residents in the future.

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Appendix I: Raw data from sUAS surveys

Appendix I – Results of Spotlight Surveys in Watchung Borough in 2019

Date	Left Search Distance (m)	Right Search Distance (m)	Left Deer Count	Right Deer Count	x	y	Survey Section
4/3/2019 2:47	44	62	0	0	-74.446855	40.636906	WB1
4/3/2019 2:49	27	26	0	0	-74.444841	40.636916	WB1
4/3/2019 2:45	24	44	1	0	-74.449099	40.637566	WB1
4/3/2019 2:46	41	71	0	0	-74.446491	40.638631	WB1
4/3/2019 2:21	72	63	0	3	-74.444536	40.639542	WB1
4/3/2019 2:42	14	15	0	1	-74.446441	40.641173	WB1
4/3/2019 4:21	19	33	0	0	-74.458495	40.642434	WB1
4/3/2019 2:41	44	17	0	0	-74.446807	40.642864	WB1
4/3/2019 2:34	122	106	0	0	-74.446889	40.644135	WB1
4/3/2019 4:15	16	113	0	0	-74.451219	40.644487	WB1
4/3/2019 2:31	31	42	0	0	-74.448712	40.644912	WB1
4/3/2019 4:17	35	67	0	0	-74.454463	40.645787	WB1
4/3/2019 2:25	72	33	7	1	-74.44399	40.645902	WB1
4/3/2019 2:57	77	99	0	0	-74.440321	40.646128	WB1
4/3/2019 2:29	35	30	0	0	-74.447903	40.646617	WB1
4/3/2019 4:16	28	33	0	0	-74.452408	40.646703	WB1
4/3/2019 2:27	21	43	0	0	-74.445119	40.648325	WB1
4/3/2019 4:36	27	31	0	0	-74.447812	40.648345	WB1
4/3/2019 4:34	20	39	0	0	-74.449985	40.648845	WB1
4/3/2019 2:59	51	60	0	0	-74.442432	40.648863	WB1
4/3/2019 3:13	28	52	0	0	-74.434164	40.650012	WB1
4/3/2019 4:37	30	33	0	0	-74.445796	40.650308	WB1
4/3/2019 4:33	53	20	0	0	-74.448836	40.650411	WB1
4/3/2019 3:11	53	26	0	0	-74.436414	40.651912	WB1
4/3/2019 4:31	27	20	0	0	-74.448263	40.652173	WB1
4/3/2019 4:44	35	37	0	0	-74.441761	40.65254	WB1
4/3/2019 4:38	30	34	0	0	-74.445766	40.652847	WB1
4/3/2019 4:45	14	60	0	0	-74.439168	40.653424	WB1
4/3/2019 3:15	24	28	0	0	-74.433424	40.653847	WB1
4/3/2019 4:03	21	39	0	0	-74.424084	40.654248	WB1
4/3/2019 4:39	31	57	0	0	-74.44283	40.654415	WB1
4/3/2019 4:48	47	27	0	0	-74.436419	40.654815	WB1
4/3/2019 4:00	41	35	0	4	-74.430014	40.655745	WB1
4/3/2019 4:46	24	48	3	2	-74.439263	40.656058	WB1
4/3/2019 5:07	35	64	0	0	-74.433218	40.656144	WB1
4/3/2019 4:08	48	64	0	2	-74.427671	40.656274	WB1
4/3/2019 4:13	24	36	0	0	-74.417573	40.656478	WB1
4/3/2019 4:40	20	17	0	0	-74.440205	40.656498	WB1
4/3/2019 5:03	40	20	0	0	-74.43084	40.65678	WB1
4/3/2019 5:17	15	17	0	0	-74.442831	40.656977	WB1
4/3/2019 4:49	65	40	0	0	-74.436641	40.65722	WB1
4/3/2019 4:57	55	25	0	1	-74.433344	40.658344	WB1
4/3/2019 5:05	28	41	0	0	-74.430767	40.658413	WB1
4/3/2019 4:06	65	10	0	0	-74.424504	40.658597	WB1
4/3/2019 5:02	22	32	0	0	-74.428573	40.658659	WB1
4/3/2019 5:01	33	30	0	0	-74.426307	40.659222	WB1
4/3/2019 4:59	39	36	1	2	-74.430844	40.660343	WB1
4/3/2019 5:00	35	24	0	0	-74.427619	40.660936	WB1
4/3/2019 4:52	17	33	0	0	-74.432904	40.661163	WB1
4/3/2019 5:13	21	15	0	0	-74.434391	40.663447	WB1
4/3/2019 1:41	11	13	0	0	-74.440442	40.630579	WB2
4/3/2019 1:47	25	37	0	0	-74.439531	40.631954	WB2
4/3/2019 1:45	15	35	1	2	-74.437099	40.632644	WB2
4/3/2019 1:15	10	65	0	1	-74.432177	40.633765	WB2
4/3/2019 1:49	19	22	0	0	-74.441846	40.633873	WB2
4/3/2019 1:51	15	36	0	0	-74.441269	40.634438	WB2
4/3/2019 2:04	53	14	4	0	-74.436461	40.635399	WB2
4/3/2019 1:54	62	31	0	0	-74.441286	40.635805	WB2
4/3/2019 1:33	46	39	4	0	-74.429741	40.636139	WB2
4/3/2019 2:06	41	16	0	0	-74.434151	40.637247	WB2
4/3/2019 1:56	25	52	0	0	-74.442713	40.637854	WB2
4/3/2019 1:35	28	37	1	0	-74.427418	40.638112	WB2
4/3/2019 2:10	40	39	0	0	-74.435557	40.638321	WB2
4/3/2019 2:16	21	66	3	0	-74.441503	40.638408	WB2

4/3/2019 1:59	31	64	2	0	-74.439284	40.638756	WB2
4/3/2019 2:12	7	14	0	0	-74.437352	40.638913	WB2
4/3/2019 2:08	29	38	0	0	-74.433443	40.63911	WB2
4/3/2019 2:14	10	30	0	0	-74.438745	40.640007	WB2
4/3/2019 4:47	26	35	0	0	-74.430286	40.6402	WB2
4/3/2019 2:19	27	31	0	0	-74.441329	40.641071	WB2
4/3/2019 4:45	12	56	0	0	-74.427214	40.641768	WB2
4/3/2019 4:50	7	50	0	0	-74.431946	40.641908	WB2
4/3/2019 4:51	23	32	0	0	-74.435538	40.642096	WB2
4/3/2019 5:13	18	9	0	2	-74.422523	40.64242	WB2
4/3/2019 2:55	41	53	0	0	-74.436816	40.643161	WB2
4/3/2019 2:53	24	21	0	2	-74.439946	40.643182	WB2
4/3/2019 2:23	38	46	0	0	-74.442666	40.643441	WB2
4/3/2019 4:54	17	44	0	0	-74.429678	40.643538	WB2
4/3/2019 4:44	21	39	0	0	-74.424782	40.643677	WB2
4/3/2019 3:38	20	47	0	4	-74.435829	40.644072	WB2
4/3/2019 3:28	72	17	0	0	-74.426348	40.644097	WB2
4/3/2019 5:05	19	29	3	0	-74.40864	40.644315	WB2
4/3/2019 3:35	92	59	0	0	-74.433537	40.644583	WB2
4/3/2019 3:31	44	42	0	0	-74.429921	40.64545	WB2
4/3/2019 4:42	18	30	0	3	-74.421641	40.645866	WB2
4/3/2019 3:06	77	61	4	1	-74.436216	40.646114	WB2
4/3/2019 3:27	48	8	8	0	-74.424851	40.646124	WB2
4/3/2019 3:23	19	38	0	0	-74.429892	40.646636	WB2
4/3/2019 3:40	108	27	1	0	-74.433827	40.646869	WB2
4/3/2019 4:36	71	112	0	0	-74.419214	40.647799	WB2
4/3/2019 3:47	40	86	0	4	-74.425161	40.647884	WB2
4/3/2019 3:24	85	25	0	0	-74.426433	40.647986	WB2
4/3/2019 3:53	12	61	0	0	-74.424204	40.648037	WB2
4/3/2019 4:39	29	94	0	0	-74.42166	40.64807	WB2
4/3/2019 3:17	30	8	0	0	-74.431167	40.649135	WB2
4/3/2019 4:37	114	61	0	0	-74.41887	40.649848	WB2
4/3/2019 4:34	19	29	0	4	-74.416313	40.649909	WB2
4/3/2019 3:19	62	24	0	4	-74.430249	40.650518	WB2
4/3/2019 3:56	45	19	0	0	-74.421139	40.650735	WB2
4/3/2019 3:45	80	103	0	0	-74.42637	40.650997	WB2
4/3/2019 4:31	35	76	0	0	-74.413519	40.651508	WB2
4/3/2019 3:51	15	53	0	0	-74.423576	40.651555	WB2
4/3/2019 3:43	13	56	0	0	-74.428463	40.652926	WB2
4/3/2019 4:30	9	32	0	0	-74.410139	40.653303	WB2
4/3/2019 4:28	25	36	0	0	-74.407052	40.65574	WB2
4/3/2019 4:19	50	37	0	1	-74.409987	40.655837	WB2
4/3/2019 4:22	34	133	3	4	-74.403841	40.656343	WB2
4/3/2019 4:20	11	17	0	0	-74.406336	40.657281	WB2
4/3/2019 4:25	32	5	0	0	-74.403528	40.658632	WB2
4/3/2019 1:39	0	37	0	24	-74.476693	40.618865	WB3
4/3/2019 1:37	29	30	0	0	-74.479489	40.619063	WB3
4/3/2019 1:41	33	32	0	0	-74.473458	40.619517	WB3
4/3/2019 1:55	13	28	0	2	-74.466204	40.619826	WB3
4/3/2019 2:28	77	39	0	2	-74.461028	40.620223	WB3
4/3/2019 1:53	26	27	0	0	-74.468997	40.620688	WB3
4/3/2019 1:48	40	36	2	0	-74.477679	40.621294	WB3
4/3/2019 1:43	34	21	0	0	-74.474162	40.621482	WB3
4/3/2019 2:41	55	32	0	0	-74.464272	40.621655	WB3
4/3/2019 1:35	70	12	0	0	-74.481374	40.621882	WB3
4/3/2019 2:02	33	34	0	0	-74.471898	40.622008	WB3
4/3/2019 2:30	54	114	0	2	-74.458081	40.622706	WB3
4/3/2019 2:00	20	42	0	0	-74.466613	40.62331	WB3
4/3/2019 1:45	50	11	0	0	-74.476108	40.62356	WB3
4/3/2019 2:26	77	34	0	0	-74.461628	40.623596	WB3
4/3/2019 2:31	56	48	0	0	-74.455199	40.623928	WB3
4/3/2019 2:42	41	61	0	0	-74.465097	40.623939	WB3
4/3/2019 2:09	29	53	2	0	-74.467027	40.624422	WB3
4/3/2019 2:05	53	33	0	0	-74.469898	40.624628	WB3
4/3/2019 2:35	69	48	0	4	-74.456458	40.625309	WB3
4/3/2019 2:32	72	37	0	0	-74.453378	40.625997	WB3
4/3/2019 2:15	8	27	0	0	-74.465511	40.626253	WB3

4/3/2019 2:25	32	46	0	0	-74.462387	40.626443	WB3
4/3/2019 2:11	73	55	1	0	-74.467333	40.626889	WB3
4/3/2019 4:09	72	32	0	0	-74.451344	40.627403	WB3
4/3/2019 2:37	58	29	6	0	-74.459545	40.627542	WB3
4/3/2019 2:34	46	29	3	0	-74.455164	40.627801	WB3
4/3/2019 2:47	26	47	0	0	-74.461302	40.629173	WB3
4/3/2019 4:06	41	41	0	0	-74.452231	40.629484	WB3
4/3/2019 2:17	39	60	0	0	-74.463644	40.629526	WB3
4/3/2019 2:53	77	26	0	0	-74.457982	40.630081	WB3
4/3/2019 2:50	45	42	0	0	-74.459336	40.63086	WB3
4/3/2019 4:08	1	35	0	1	-74.454352	40.630899	WB3
4/3/2019 3:58	20	34	0	0	-74.452242	40.631553	WB3
4/3/2019 3:56	31	53	0	0	-74.454808	40.631641	WB3
4/3/2019 4:03	19	21	0	0	-74.44938	40.631831	WB3
4/3/2019 3:59	45	16	0	0	-74.45332	40.63257	WB3
4/3/2019 3:53	33	33	0	1	-74.456497	40.632756	WB3
4/3/2019 2:20	40	56	0	0	-74.465381	40.633206	WB3
4/3/2019 3:50	46	27	3	2	-74.455597	40.633612	WB3
4/3/2019 4:02	62	22	0	0	-74.45027	40.634137	WB3
4/3/2019 3:47	22	36	1	0	-74.453787	40.634377	WB3
4/3/2019 2:55	57	19	2	0	-74.45929	40.634947	WB3
4/3/2019 3:42	30	24	0	0	-74.448095	40.635188	WB3
4/3/2019 4:01	90	10	0	0	-74.452963	40.635333	WB3
4/3/2019 2:21	44	36	0	0	-74.466337	40.635671	WB3
4/3/2019 3:45	32	41	0	0	-74.452671	40.636485	WB3
4/3/2019 3:41	20	33	0	0	-74.450179	40.636553	WB3
4/3/2019 3:08	23	48	0	0	-74.457825	40.636562	WB3
4/3/2019 2:57	37	6	2	0	-74.460619	40.637031	WB3
4/3/2019 3:09	22	33	0	0	-74.45686	40.637519	WB3
4/3/2019 3:19	36	30	0	0	-74.453346	40.638117	WB3
4/3/2019 3:01	35	16	0	0	-74.460067	40.638243	WB3
4/3/2019 3:21	47	41	1	0	-74.454162	40.638528	WB3
4/3/2019 3:00	53	10	0	0	-74.461865	40.63866	WB3
4/3/2019 3:24	33	66	0	0	-74.450854	40.638748	WB3
4/3/2019 3:06	18	48	0	0	-74.457648	40.638991	WB3
4/3/2019 3:25	40	10	0	0	-74.452659	40.639523	WB3
4/3/2019 3:03	50	7	0	0	-74.460675	40.639952	WB3
4/3/2019 3:26	58	36	0	0	-74.454459	40.640237	WB3
4/3/2019 3:17	56	36	0	0	-74.456987	40.640481	WB3
4/3/2019 3:05	40	18	0	0	-74.459625	40.640548	WB3
4/3/2019 3:35	55	10	0	0	-74.452041	40.641374	WB3
4/3/2019 3:33	64	23	0	0	-74.454124	40.64148	WB3
4/3/2019 3:12	115	75	0	0	-74.456753	40.641797	WB3
4/3/2019 3:37	27	5	0	0	-74.451384	40.641823	WB3
4/3/2019 3:28	34	38	0	0	-74.454968	40.642627	WB3
4/3/2019 3:30	48	16	0	0	-74.453473	40.644315	WB3
4/21/2019 2:32			0	0	-74.44476	40.63693	WB1
4/21/2019 2:31			0	0	-74.446792	40.636958	WB1
4/21/2019 2:29			0	0	-74.448944	40.637581	WB1
4/21/2019 2:30			0	0	-74.446442	40.638599	WB1
4/21/2019 2:27			0	0	-74.446462	40.641181	WB1
4/21/2019 4:10			0	0	-74.458552	40.64251	WB1
4/21/2019 2:39			0	0	-74.446852	40.642844	WB1
4/21/2019 2:48			4	5	-74.446916	40.644606	WB1
4/21/2019 2:46			0	0	-74.448619	40.644736	WB1
4/21/2019 2:41			1	0	-74.443719	40.645357	WB1
4/21/2019 4:08			0	0	-74.455168	40.645618	WB1
4/21/2019 3:14			0	0	-74.451167	40.645755	WB1
4/21/2019 3:00			0	0	-74.440636	40.646433	WB1
4/21/2019 2:44			0	0	-74.448128	40.646438	WB1
4/21/2019 4:07			0	0	-74.452204	40.646764	WB1
4/21/2019 2:43			0	0	-74.444865	40.64828	WB1
4/21/2019 3:22			0	0	-74.447569	40.648599	WB1
4/21/2019 3:21			0	0	-74.449902	40.64865	WB1
4/21/2019 2:57			0	0	-74.442448	40.648741	WB1
4/21/2019 3:08			0	0	-74.434274	40.650039	WB1
4/21/2019 3:23			0	0	-74.445692	40.65039	WB1

4/21/2019 3:18			0	0	-74.448745	40.650391	WB1
4/21/2019 3:09			0	0	-74.436293	40.651829	WB1
4/21/2019 3:17			0	9	-74.448258	40.65226	WB1
4/21/2019 3:30			0	0	-74.442178	40.652267	WB1
4/21/2019 3:24			0	0	-74.445838	40.652866	WB1
4/21/2019 3:31			0	0	-74.439196	40.653475	WB1
4/21/2019 3:07			0	0	-74.433553	40.65393	WB1
4/21/2019 3:15			0	0	-74.424087	40.654284	WB1
4/21/2019 3:25			0	0	-74.442767	40.654542	WB1
4/21/2019 3:33			0	0	-74.436473	40.654931	WB1
4/21/2019 3:13			0	4	-74.430111	40.655817	WB1
4/21/2019 3:46			0	0	-74.43338	40.655889	WB1
4/21/2019 3:31			0	0	-74.439467	40.656077	WB1
4/21/2019 3:18			0	0	-74.427716	40.656345	WB1
4/21/2019 3:24			0	0	-74.417457	40.656585	WB1
4/21/2019 3:27			2	1	-74.440011	40.656642	WB1
4/21/2019 3:43			0	0	-74.430694	40.656824	WB1
4/21/2019 3:58			0	0	-74.442769	40.656877	WB1
4/21/2019 3:34			0	0	-74.436592	40.657326	WB1
4/21/2019 3:45			0	0	-74.430771	40.658308	WB1
4/21/2019 3:38			0	1	-74.433271	40.658391	WB1
4/21/2019 3:42			0	0	-74.428507	40.658517	WB1
4/21/2019 3:19			0	0	-74.424639	40.658566	WB1
4/21/2019 3:41			0	0	-74.426262	40.659355	WB1
4/21/2019 3:39			0	0	-74.430969	40.660455	WB1
4/21/2019 3:40			0	0	-74.427574	40.660998	WB1
4/21/2019 3:36			0	0	-74.433071	40.66105	WB1
4/21/2019 3:53			0	0	-74.434462	40.663382	WB1
4/21/2019 2:07			0	0	-74.440397	40.630661	WB2
4/21/2019 2:02			1	2	-74.439598	40.63187	WB2
4/21/2019 2:03			0	0	-74.437171	40.632646	WB2
4/21/2019 2:00			1	0	-74.442012	40.633834	WB2
4/21/2019 1:55			0	0	-74.441131	40.634299	WB2
4/21/2019 1:47			0	3	-74.436218	40.635619	WB2
4/21/2019 1:49			0	0	-74.441328	40.635682	WB2
4/21/2019 1:45			4	2	-74.43398	40.637339	WB2
4/21/2019 1:51			0	0	-74.44285	40.637811	WB2
4/21/2019 2:14			0	0	-74.435449	40.638253	WB2
4/21/2019 2:20			0	0	-74.441484	40.638414	WB2
4/21/2019 1:52			0	0	-74.439262	40.638507	WB2
4/21/2019 2:17			0	0	-74.437191	40.638854	WB2
4/21/2019 2:15			0	0	-74.433712	40.639152	WB2
4/21/2019 2:23			0	1	-74.44448	40.639538	WB2
4/21/2019 2:18			0	0	-74.438877	40.63986	WB2
4/21/2019 1:42			1	2	-74.430401	40.640164	WB2
4/21/2019 2:22			0	1	-74.44121	40.641077	WB2
4/21/2019 3:55			0	0	-74.43181	40.641988	WB2
4/21/2019 1:40			0	0	-74.426967	40.642019	WB2
4/21/2019 3:56			0	0	-74.435318	40.642092	WB2
4/21/2019 4:15			0	0	-74.422351	40.642466	WB2
4/21/2019 2:53			0	0	-74.43988	40.643108	WB2
4/21/2019 2:55			0	0	-74.43679	40.643242	WB2
4/21/2019 2:25			0	0	-74.44298	40.643465	WB2
4/21/2019 3:52			0	0	-74.429733	40.643611	WB2
4/21/2019 1:34			0	0	-74.424808	40.643735	WB2
4/21/2019 3:50			1	0	-74.435738	40.644005	WB2
4/21/2019 3:44			0	0	-74.426298	40.644171	WB2
4/21/2019 3:49			0	0	-74.433494	40.64458	WB2
4/21/2019 3:47			0	0	-74.429846	40.645471	WB2
4/21/2019 1:33			0	0	-74.421672	40.645815	WB2
4/21/2019 3:02			0	0	-74.436173	40.64619	WB2
4/21/2019 3:46			0	0	-74.42492	40.646225	WB2
4/21/2019 3:58			0	0	-74.43348	40.64654	WB2
4/21/2019 3:41			0	0	-74.429923	40.646769	WB2
4/21/2019 1:27			0	0	-74.419325	40.647801	WB2
4/21/2019 1:30			0	0	-74.421654	40.647977	WB2
4/21/2019 3:35			0	0	-74.425135	40.648021	WB2

4/21/2019 3:43			1	0	-74.426551	40.64803	WB2
4/21/2019 3:29			0	0	-74.42386	40.648181	WB2
4/21/2019 3:37			0	0	-74.430996	40.649273	WB2
4/21/2019 1:25			0	7	-74.416427	40.649851	WB2
4/21/2019 1:29			0	1	-74.419218	40.649895	WB2
4/21/2019 3:39			0	0	-74.430301	40.650439	WB2
4/21/2019 3:28			0	0	-74.421286	40.65078	WB2
4/21/2019 3:33			0	3	-74.426274	40.651071	WB2
4/21/2019 1:24			0	0	-74.413303	40.651574	WB2
4/21/2019 3:27			0	0	-74.423558	40.65165	WB2
4/21/2019 3:32			0	0	-74.428491	40.652907	WB2
4/21/2019 1:22			0	0	-74.410371	40.653148	WB2
4/21/2019 1:22			0	0	-74.410172	40.653302	WB2
4/21/2019 4:04			0	0	-74.407518	40.655143	WB2
4/21/2019 1:23			0	0	-74.476792	40.618865	WB3
4/21/2019 1:24			0	0	-74.479499	40.619205	WB3
4/21/2019 1:31			0	0	-74.473534	40.619492	WB3
4/21/2019 1:18			0	0	-74.466032	40.619789	WB3
4/21/2019 2:00			2	3	-74.46089	40.620135	WB3
4/21/2019 1:21			0	0	-74.469154	40.620762	WB3
4/21/2019 1:30			0	0	-74.47751	40.621133	WB3
4/21/2019 1:28			0	0	-74.474432	40.621325	WB3
4/21/2019 1:56			0	0	-74.464327	40.621689	WB3
4/21/2019 1:25			2	0	-74.481411	40.621839	WB3
4/21/2019 1:39			0	0	-74.471761	40.622195	WB3
4/21/2019 2:01			0	3	-74.458077	40.622673	WB3
4/21/2019 1:27			1	0	-74.475932	40.62315	WB3
4/21/2019 1:34			0	0	-74.466778	40.623316	WB3
4/21/2019 1:55			0	0	-74.461654	40.623571	WB3
4/21/2019 1:57			0	0	-74.465012	40.623809	WB3
4/21/2019 2:02			0	0	-74.455098	40.623974	WB3
4/21/2019 1:41			0	0	-74.467117	40.624339	WB3
4/21/2019 1:43			2	0	-74.469873	40.624595	WB3
4/21/2019 2:05			0	7	-74.456638	40.625253	WB3
4/21/2019 2:03			1	0	-74.453562	40.625985	WB3
4/21/2019 1:54			0	0	-74.462334	40.626288	WB3
4/21/2019 1:51			0	0	-74.465502	40.626292	WB3
4/21/2019 1:42			0	0	-74.467361	40.626656	WB3
4/21/2019 2:07			1	0	-74.459636	40.62758	WB3
4/21/2019 2:04			0	3	-74.455271	40.627673	WB3
4/21/2019 2:11			0	2	-74.451458	40.627674	WB3
4/21/2019 2:19			6	0	-74.452173	40.629454	WB3
4/21/2019 1:49			0	0	-74.463713	40.629519	WB3
4/21/2019 2:31			0	0	-74.461302	40.629672	WB3
4/21/2019 2:29			0	0	-74.458569	40.629896	WB3
4/21/2019 2:12			0	0	-74.454348	40.630922	WB3
4/21/2019 2:28			0	0	-74.4594	40.630949	WB3
4/21/2019 2:21			0	0	-74.454903	40.631407	WB3
4/21/2019 2:13			0	0	-74.452319	40.631569	WB3
4/21/2019 2:18			0	0	-74.449348	40.631815	WB3
4/21/2019 2:15			0	0	-74.453295	40.632639	WB3
4/21/2019 2:26			0	0	-74.456518	40.633091	WB3
4/21/2019 1:46			2	0	-74.465436	40.633177	WB3
4/21/2019 2:26			0	0	-74.455636	40.633971	WB3
4/21/2019 2:16			0	0	-74.450093	40.634131	WB3
4/21/2019 2:59			0	0	-74.453731	40.634269	WB3
4/21/2019 3:00			0	0	-74.447883	40.634981	WB3
4/21/2019 2:35			0	0	-74.459388	40.634981	WB3
4/21/2019 2:15			0	0	-74.452939	40.635294	WB3
4/21/2019 1:47			0	0	-74.466357	40.63567	WB3
4/21/2019 2:55			0	0	-74.452803	40.636425	WB3
4/21/2019 2:41			0	0	-74.457728	40.636431	WB3
4/21/2019 3:00			0	0	-74.449853	40.636464	WB3
4/21/2019 2:36			0	0	-74.460668	40.636962	WB3
4/21/2019 2:42			1	0	-74.456947	40.637606	WB3
4/21/2019 2:52			0	0	-74.453371	40.638023	WB3
4/21/2019 2:39			0	0	-74.460037	40.638218	WB3

4/21/2019 3:04			0	0	-74.450841	40.638565	WB3
4/21/2019 2:54			0	0	-74.454315	40.638605	WB3
4/21/2019 2:37			0	0	-74.461903	40.638708	WB3
4/21/2019 2:43			0	0	-74.457587	40.638977	WB3
4/21/2019 3:05			0	0	-74.452698	40.639428	WB3
4/21/2019 2:40			0	0	-74.460601	40.639797	WB3
4/21/2019 3:07			0	0	-74.454457	40.64025	WB3
4/21/2019 2:49			0	0	-74.456843	40.640409	WB3
4/21/2019 2:44			0	0	-74.459616	40.64054	WB3
4/21/2019 4:14			0	0	-74.451311	40.641106	WB3
4/21/2019 3:06			0	3	-74.452124	40.641273	WB3
4/21/2019 3:11			0	0	-74.454104	40.641432	WB3
4/21/2019 2:46			0	0	-74.457282	40.641706	WB3
4/21/2019 3:09			0	0	-74.454806	40.642672	WB3
4/21/2019 4:13			0	0	-74.45134	40.643848	WB3
4/21/2019 3:08			0	0	-74.453659	40.644355	WB3

Appendix II – Results of Drone Surveys in Watchung Borough in 2019

Date	# Deer Observed	x	y	Study Subsite	Area(mi ²)
4/2/2019	1	-74.46169	40.630987	A	0.2305
4/2/2019	12	-74.463434	40.63616	A	0.2305
4/2/2019	3	-74.465695	40.63722	A	0.2305
4/2/2019	1	-74.466466	40.637807	A	0.2305
4/2/2019	3	-74.461805	40.632304	A	0.2305
4/2/2019	1	-74.462852	40.631577	A	0.2305
4/2/2019	4	-74.466902	40.634794	A	0.2305
4/2/2019	1	-74.466413	40.635281	A	0.2305
4/2/2019	2	-74.467125	40.636988	A	0.2305
4/2/2019	1	-74.468227	40.636427	A	0.2305
4/2/2019	1	-74.446303	40.642133	B	0.1976
4/2/2019	3	-74.450033	40.640626	B	0.1976
4/2/2019	1	-74.448261	40.644814	B	0.1976
4/2/2019	1	-74.449242	40.641867	B	0.1976
4/2/2019	1	-74.448357	40.643902	B	0.1976
4/2/2019	5	-74.443432	40.646226	B	0.1976
4/2/2019	3	-74.446514	40.646196	B	0.1976
4/11/2019	6	-74.480773	40.622745	A	1.418726
4/11/2019	2	-74.480663	40.623855	A	1.418726
4/11/2019	4	-74.47705	40.625218	A	1.418726
4/11/2019	1	-74.476291	40.626206	A	1.418726
4/11/2019	2	-74.474711	40.624723	A	1.418726
4/11/2019	3	-74.469979	40.623383	A	1.418726
4/11/2019	2	-74.472868	40.621602	A	1.418726
4/11/2019	1	-74.475712	40.619666	A	1.418726
4/11/2019	2	-74.475421	40.62335	A	1.418726
4/11/2019	3	-74.474891	40.622607	A	1.418726
4/11/2019	2	-74.473053	40.620716	A	1.418726
4/11/2019	5	-74.47381	40.618517	A	1.418726
4/11/2019	3	-74.478896	40.620834	A	1.418726
4/11/2019	6	-74.470923	40.62718	A	1.418726
4/11/2019	7	-74.470348	40.627305	A	1.418726
4/11/2019	2	-74.469751	40.627232	A	1.418726
4/11/2019	4	-74.47089	40.630871	A	1.418726
4/11/2019	4	-74.466617	40.630029	A	1.418726
4/11/2019	3	-74.472735	40.62529	A	1.418726
4/11/2019	6	-74.459625	40.633504	A	1.418726
4/11/2019	2	-74.464953	40.631232	A	1.418726

4/11/2019	2	-74.464973	40.631617	A	1.418726
4/11/2019	4	-74.466809	40.633624	A	1.418726
4/11/2019	2	-74.467088	40.63651	A	1.418726
4/11/2019	2	-74.463272	40.630595	A	1.418726
4/11/2019	1	-74.461973	40.634492	A	1.418726
4/11/2019	3	-74.461652	40.633829	A	1.418726
4/11/2019	2	-74.460682	40.633998	A	1.418726
4/11/2019	3	-74.461367	40.634614	A	1.418726
4/11/2019	2	-74.462355	40.636701	A	1.418726
4/11/2019	6	-74.460299	40.6356	A	1.418726
4/11/2019	1	-74.459617	40.634272	A	1.418726
4/11/2019	1	-74.458949	40.634442	A	1.418726
4/11/2019	4	-74.455416	40.63633	A	1.418726
4/11/2019	0	-74.459564	40.63729	A	1.418726
4/11/2019	2	-74.456359	40.638426	A	1.418726
4/11/2019	1	-74.45596	40.637763	A	1.418726
4/11/2019	1	-74.460151	40.63986	A	1.418726
4/11/2019	10	-74.456157	40.640726	A	1.418726
4/11/2019	4	-74.45544	40.640593	A	1.418726
4/11/2019	1	-74.457829	40.641742	A	1.418726
4/11/2019	1	-74.455355	40.638736	A	1.418726
4/11/2019	5	-74.458764	40.641615	A	1.418726
4/11/2019	2	-74.451529	40.641849	A	1.418726
4/11/2019	1	-74.453387	40.642803	A	1.418726
4/11/2019	2	-74.455577	40.643192	A	1.418726
4/11/2019	3	-74.457649	40.643539	A	1.418726
4/11/2019	7	-74.462134	40.62335	A	1.418726
4/11/2019	1	-74.462158	40.623096	A	1.418726
4/11/2019	3	-74.464243	40.626492	A	1.418726
4/11/2019	4	-74.4639	40.626663	A	1.418726
4/11/2019	1	-74.46369	40.62657	A	1.418726
4/11/2019	3	-74.463249	40.622705	A	1.418726
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4/11/2019	1	-74.46744	40.620213	A	1.418726
4/21/2019	1	-74.420939	40.653066	C	0.236952
4/21/2019	2	-74.421403	40.653682	C	0.236952
4/21/2019	1	-74.420289	40.652523	C	0.236952
4/21/2019	1	-74.422842	40.654184	C	0.236952
4/21/2019	1	-74.420469	40.656003	C	0.236952
4/21/2019	4	-74.423929	40.655551	C	0.236952
4/21/2019	1	-74.426527	40.654105	C	0.236952

4/21/2019	2	-74.421197	40.651434	C	0.236952
4/21/2019	2	-74.422196	40.650319	C	0.236952
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4/21/2019	1	-74.422322	40.648947	C	0.236952
4/21/2019	2	-74.423668	40.64956	C	0.236952
4/21/2019	5	-74.427901	40.65184	C	0.236952
4/21/2019	1	-74.449973	40.64329	B	0.205248
4/21/2019	4	-74.449615	40.64066	B	0.205248
4/21/2019	2	-74.449087	40.64223	B	0.205248
4/21/2019	2	-74.447206	40.642896	B	0.205248
4/21/2019	3	-74.445519	40.646044	B	0.205248
4/21/2019	4	-74.446093	40.646566	B	0.205248
4/21/2019	1	-74.446141	40.648094	B	0.205248
4/21/2019	3	-74.449046	40.646683	B	0.205248
4/21/2019	1	-74.45084	40.646178	B	0.205248
4/21/2019	1	-74.449941	40.645273	B	0.205248
4/21/2019	1	-74.447734	40.646054	B	0.205248
4/21/2019	7	-74.447811	40.645721	B	0.205248
4/21/2019	1	-74.444988	40.645907	B	0.205248
4/21/2019	1	-74.443667	40.643674	B	0.205248
4/21/2019	2	-74.444788	40.643562	B	0.205248
4/21/2019	1	-74.44506	40.64283	B	0.205248
4/21/2019	4	-74.446069	40.642836	B	0.205248
4/21/2019	1	-74.443765	40.648085	B	0.205248
4/21/2019	1	-74.462639	40.634526	A	0.459047
4/21/2019	2	-74.465342	40.636818	A	0.459047
4/21/2019	1	-74.46599	40.637869	A	0.459047
4/21/2019	3	-74.462719	40.635827	A	0.459047
4/21/2019	6	-74.463413	40.630713	A	0.459047
4/21/2019	3	-74.46143	40.63226	A	0.459047
4/21/2019	5	-74.461018	40.632072	A	0.459047
4/21/2019	1	-74.466149	40.631183	A	0.459047
4/21/2019	6	-74.466154	40.631827	A	0.459047
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4/21/2019	5	-74.466382	40.628947	A	0.459047
4/21/2019	5	-74.46713	40.62807	A	0.459047
4/21/2019	3	-74.466322	40.63051	A	0.459047
4/21/2019	3	-74.469478	40.62736	A	0.459047
4/21/2019	2	-74.469224	40.627663	A	0.459047
4/21/2019	3	-74.467276	40.630115	A	0.459047
4/21/2019	1	-74.46793	40.631649	A	0.459047

4/21/2019	1	-74.467164	40.631483	A	0.459047
4/21/2019	1	-74.47449	40.632313	A	0.459047
4/21/2019	1	-74.471875	40.634601	A	0.459047
4/21/2019	2	-74.472123	40.631602	A	0.459047
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4/21/2019	1	-74.4746	40.629973	A	0.459047
4/21/2019	2	-74.472055	40.627171	A	0.459047
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